Technical Report
CMU/SEI-96-TR-018
ESC-TR-96-018

Carnegie-Mellon University
Software Engineering Institute

Concept of Operations for the ESC Product Line Approach

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August 30, 1996

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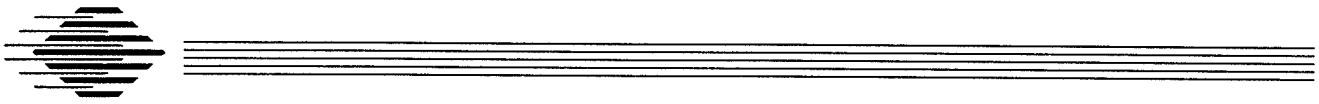

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This report was prepared for the

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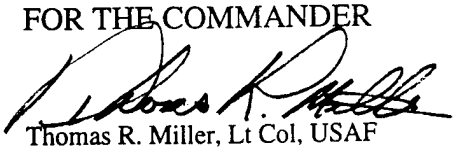

Thomas R. Miller, Lt Col, USAF
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This work is sponsored by the U.S. Department of Defense.

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Executive Summary

Radically different approaches to software acquisition are required to support the procurement of mission-critical systems that are increasingly dependent on software. These new approaches are also necessary to take advantage of the most current, proven technology in available software. These new demands must be met despite the expectation that the Air Force Electronic Systems Center (ESC) will radically reduce its staffing levels over the next two years, and that additional reductions are planned in the future. Given a severely reduced workforce, technical and management techniques will be necessary to meet the challenges of increased software capability, avoidance of obsolescence, and acquisition of software intensive-systems of increased quality. The product line approach described in this Concept of Operations is one approach that can meet these challenges and be implemented today.

Lt General C. E. Franklin, Commander of ESC, has stated:

> *"ESC programs are generally variations of a theme, such as command and control centers, communications systems, intelligence centers, etc....these product line systems can be identified in the future year development plan process and can be represented by a generic architecture, or domain, to facilitate reuse and rapid prototyping"* [Franklin 94].

This document describes the Concept of Operations (ConOps) and transition strategy for the product line approach to software systems development at the ESC, Hanscom Air Force Base, Massachusetts. This document defines the organizations implementing the product line approach and the processes used by the organizations. It describes the roles and responsibilities, and the relationships among the organizations. The processes needed to implement software system development using the product line approach are described at a high level and will be further detailed and refined as the product line approach is implemented at ESC.

A product line for software-intensive systems is a collection of systems that addresses a common set of system requirements for a particular business activity or mission. Products in the product line are customized from fundamental requirements, standard product line architectures, and component assets rather than built from scratch. The System Program Office (SPO) and users work with industry-supported product line organizations to establish their needs. These organizations develop systems in the product line based on the product line architecture and assets and deliver systems for fielding to users.

The move to a product line approach will require changes in the current way of doing business. To reduce redundancy, the product line approach will require establishing product lines for ESC by consolidating engineering capability in product line engineering centers managed at the Designated Acquisition Commander level. The Government will take responsibility for product line architectures and other assets developed by the engineering centers. The SPOs can depend on the engineering centers for general engineering services and contracts for system delivery, thus allowing the SPO to concentrate on program management and on the interface with users.

In addition to establishing product lines, the product line approach to system delivery requires establishing the product line infrastructure that will deliver precedented systems. The SPO, acting as acquisition agent, continues to provide a direct interface with the user in the field in making the decisions to procure a new or upgraded system. Working with the product line engineering centers, the SPO and the user are the customers for products under the product line approach. They remain involved throughout the development and can monitor and validate the system as it evolves from prototype to final deployment. The infrastructure, including the SPO, user, and engineering center, serves as an integrated product team for product delivery.

Figure A depicts the proposed product line infrastructure to support the product line approach to software system development at ESC. Each product line engineering center is responsible for one or more product lines, and as the product line approach evolves, the engineering centers will evolve with the addition or consolidation of product lines. In addition to the engineering centers, two other product line organizations will support the approach:

- System Architectures Group - establishes ESC-wide product line processes, monitors them, and works with product line and related organizations to improve them. It also supports product line development/evolution and architecture assessment for new systems
- Product Line Asset Support Group - supports asset use across the engineering centers.

Table 1 shows the organizational elements that participate in the product line approach.

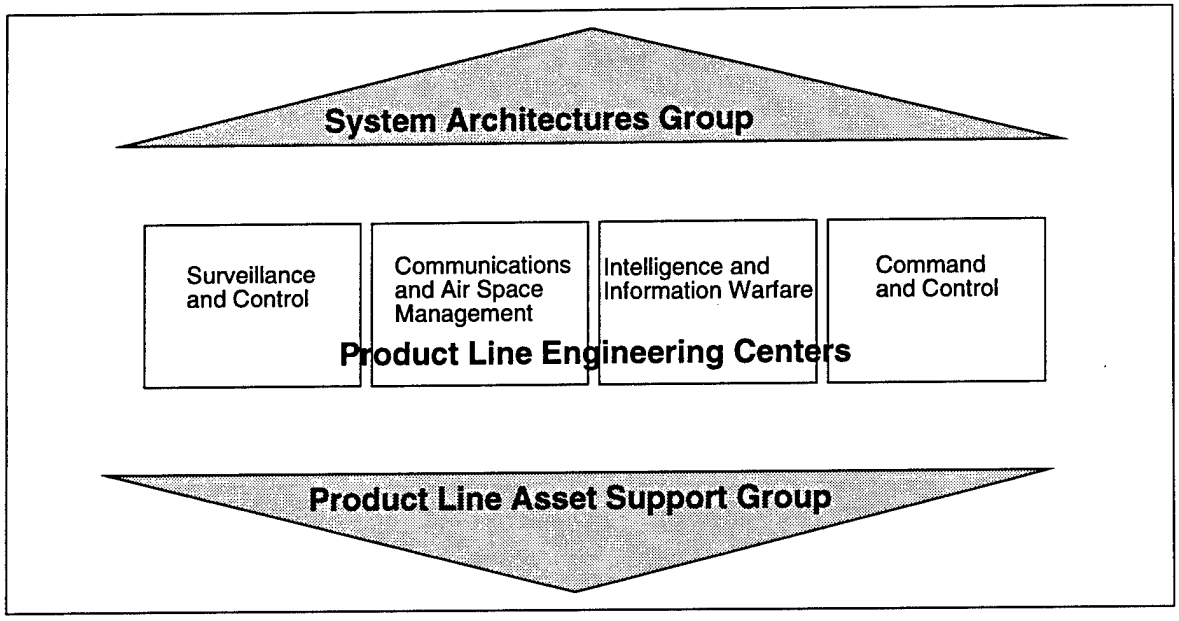

Figure A: Proposed ESC Product Line Organizational Structure

Element	Primary roles and responsibilities
User	• defines and prioritizes user needs and clarifies requirements • analyzes prototypes • validates prototype results, where appropriate • determines which, if any, of the original requirements can be tailored to conform to product line standards • performs acceptance testing of delivered systems • uses delivered systems
Program Executive Office(PEO) and Designated Acquisition Commander (DAC)	• establishes policy for product line systems approach; policy for integrating across product lines and interoperability • ensures all programs are identified • approves identification of product lines • identifies and reserves funds for product line creation and development • approves each system to be developed under the product line approach
System Program Office(SPO)	• manages system acquisition and development • serves as the primary interface to users and between other product line groups • supports product line identification • uses product line definition to assist in dialog with user for deriving operational requirements for systems • develops plans for integration across product lines • manages deployment and installation
System Architectures Group	• establishes, monitors, and improves the ESC-wide processes used in the product line approach • identifies product lines with SPOs • with engineering centers, SPOs, and users, defines and maintains the architectures for ESC systems • with engineering centers, supports the evolution and reengineering of legacy systems for conformance to product line architecture • defines standards and methods for validating conformance with architectural definitions; responsible for "building permits" and certifying conformance

Table A: Primary Responsibilities of Product Line and Related Organizations

Element	Primary roles and responsibilities
Product Line Engineering Center	• defines and maintains architectures for product lines within the engineering center and for integration across product lines • develops, procures, and evolves software (including COTS software) for product lines and for product line assets; configuration management • integrates and delivers systems by tailoring the product line architecture, specialization, and custom development per SPO requirements • supplies domain expertise in key product line technology areas • provides contract vehicle for use by SPO for product delivery
Product Line Asset Support Group	• qualifies products against product line architectures • identifies enterprise-wide assets (from COTS, GOTS, product line engineering centers) • provides a repository for ESC-wide engineering center use

Table A: Primary Responsibilities of Product Line and Related Organizations

To implement the product line approach defined here, ESC should take the following steps:

- designate a product line agent within ESC/AX, the acquisition organization at ESC, to champion the product line concept and ensure successful implementation of product lines for ESC
- provide a forum for discussion of product line concepts with users and SPOs to inform them of strategy and of new and evolving needs to understand product line requirements
- establish a concept of operations and processes for the System Architectures Group, Asset Support Group, and Product Line Engineering Centers
- develop a transition plan for each product line organization
- use the Command and Control Product Lines (CCPL) Program as the test case for the product line engineering center approach
- establish programs similar to CCPL for other product lines
- produce an implementation plan for each product line including: process definition; what will be developed (product line identification, product line architectures); business analysis (when, what costs, milestones, etc.); and measurement and tracing

This approach represents the leading edge of acquisition reform. The strategy described in this ConOps represents a dramatic change in the ESC approach to the procurement of precedented systems. It is an approach that accelerates the acquisition process while providing increased predictability and quality at lower cost.

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Concept of Operations for the ESC Product Line Approach

Abstract: This document describes the Concept of Operations (ConOps) and transition strategy for the product line approach to software systems development at the Air Force Electronic Systems Center (ESC), Hanscom Air Force Base, Massachusetts. This document defines the organizations implementing the product line approach and the processes used by the organizations. It describes the roles and responsibilities, and the relationships among the organizations. The processes needed to implement software system development using the product line approach are described at a high level and will be further detailed and refined as the product line approach is implemented at ESC.

1 Introduction

A product line for software is a collection of software systems that addresses a common set of system requirements for a particular business activity or mission. The development of software in the product line is characterized by the use of common assets including product line architectures, components, and process models. Products in the product line are built using these common assets plus some system-unique software.

Under the product line approach, the System Program Office (SPO) provides direct interface with the user in making the decisions to procure a new or upgraded system. Working with industry-supported product line organizations, the SPO and the user are the customers for products. They remain involved throughout the development and can monitor and validate the system as it evolves from prototype to final deployment (Figure 1, Part a). Rather than building from scratch, the product line organizations engineer products in the product line through customization from base requirements and standard product line architectures, and integration of components and system-unique software.The infrastructure, including the SPO, users, and product line organizations, will serve as an integrated product team for product delivery. Figure 1, Part b, illustrates this concept. As part of an overall plan for acquisition reform, ESC is promoting a product line approach to systems acquisition. Lt General C. E. Franklin, Commander of ESC, has stated:

> *"ESC programs are generally variations of a theme, such as command and control centers, communications systems, intelligence centers etc....these product line systems can be identified in the future year development plan process and can be represented by a generic architecture, or domain, to facilitate reuse and rapid prototyping"* [Franklin 94].

A team comprised of ESC, MITRE, and Software Engineering Institute (SEI) representatives produced the *Product Line Identification for ESC-Hanscom* [Cohen 95] which recommended a product line organizational structure to support the product line approach to software system development at ESC. This organizational structure is managed by the ESC Designated Acquisition Commander (DAC). The organizational structure described in that report has since evolved. The new structure, revised by Lt Gen Franklin, is depicted in Figure 2.

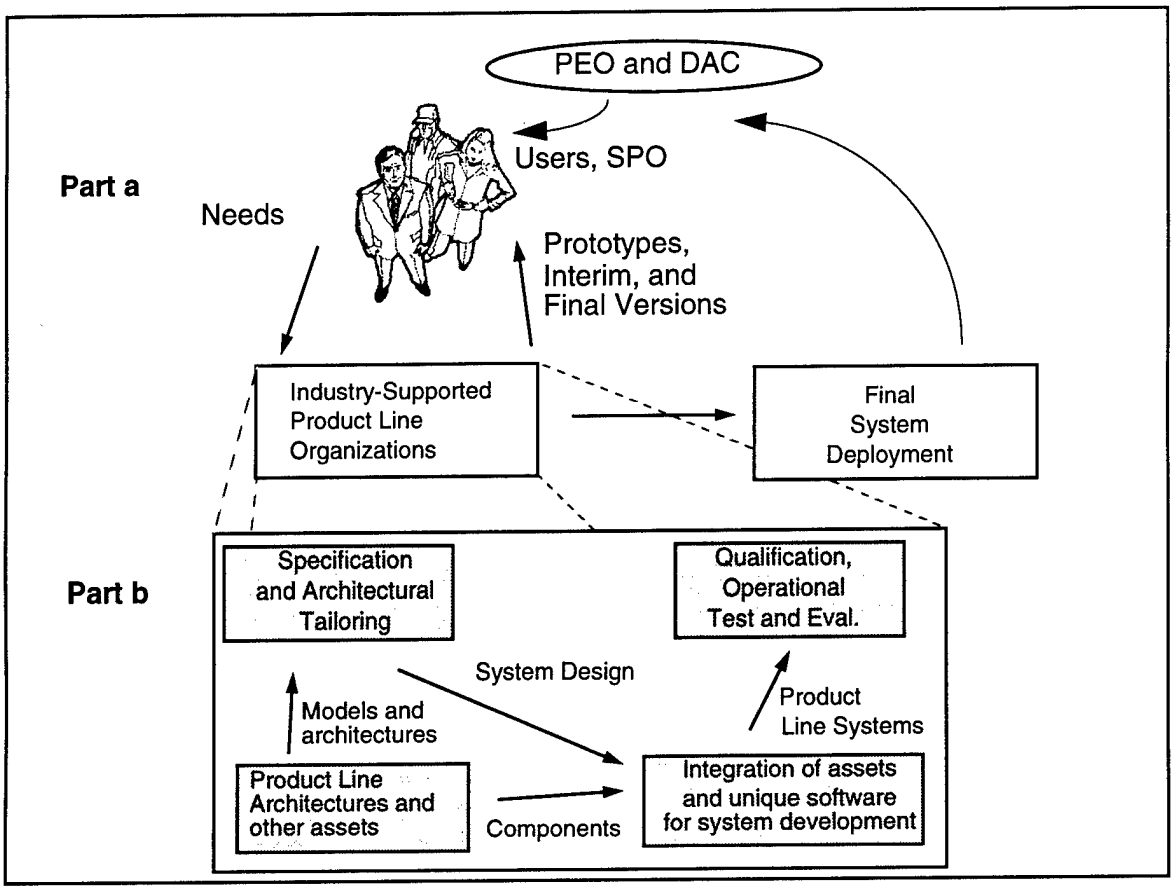

Figure 1: Product Line Concept of Operations

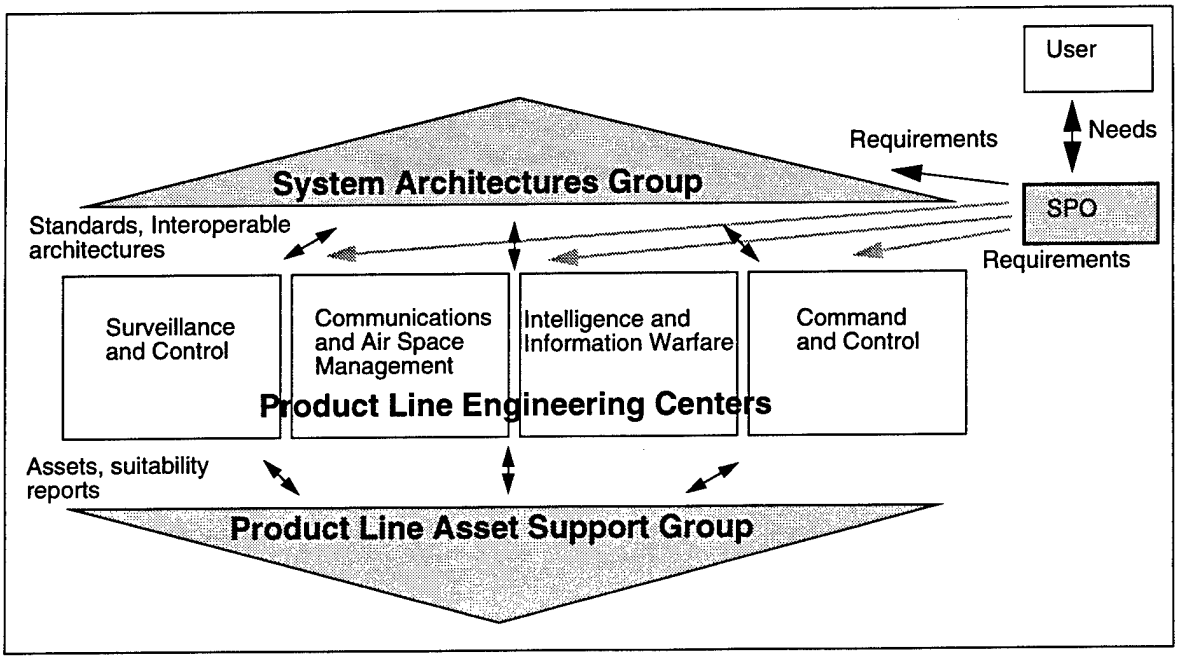

Figure 2: Proposed ESC Product Line Organizational Structure

Three key organizations work with a SPO and user to produce the system:

- System Architectures Group (SAG) supports product line architecture definition with the Product Line Engineering Centers for ESC product lines. The architecture group helps establish criteria used by the Asset Support Group for suitability testing of commercial and government off-the-shelf software. The architectures group also collaborates in building specific applications by recommending a product line source to the SPO based on SPO requirements and by analyzing needs and tailoring the product line architecture for production of the application.
- Product Line Engineering Center (PLEC) defines and evolves product line architectures with the SAG. The PLEC is also tasked by the SPO to develop prototypes where appropriate, and produce a development plan (Program Execution Plan) for product line development of a system. The engineering center provides a contract vehicle that the program office uses with a contractor to develop and deliver systems through the development phase to the customer.The engineering centers also develop assets and perform configuration management for use within their own product lines.
- Product Line Asset Support Group (PLAS) supports reuse of components through asset identification, packaging, and qualification as the basis for product line development/sustainment. With the architecture group and engineering center, ensures successful use of asset base in and across product lines. This includes supporting asset development in the engineering center and direct asset development and configuration management for cross-product line assets.

1.1 Scope

This report describes the Concept of Operations (ConOps) for the product line approach to software systems development at the Electronic Systems Center (ESC), Hanscom Air Force Base, Massachusetts. This document defines the organizations implementing the product line approach and the processes used by the organizations. It also describes the roles and responsibilities, and the relationships among the organizations.

The intent of the report is to provide the concepts required to understand the product line approach to development. This report is not intended to be an implementation or transition plan. The report explains some of the key issues involved in the transition, but does not provide managers with the detailed steps involved in planning for the transition, including establishing accountability, managing risk, scheduling, and budgeting. These must be considered when transitioning to the product line approach and setting up the product line organizations to implement the approach.

Readers of this report should be familiar with the Software Reuse Initiative Reuse Methodology Fusion Framework (RMFF) Final Report [Haddad 96] and understand the current DoD acquisition policy.

1.2 ConOps Overview

This ConOps includes the following sections:

- Section 2 provides the reasons for moving from a program orientation to the product line systems approach.
- Section 3 elaborates the functions of the SPO, PLEC, SAG, and PLAS and offers scenarios for asset and system development.
- Section 4 outlines the ESC Product Line transition strategy.
- Section 5 provides an analysis of the advantages and challenges of the new approach.

2 Rationale for Change

With the current acquisition process, it is not unusual for major systems to require 7 to 10 years to progress from conceptualization through research and development, design, integration and test to deployment. We are continuing to relearn lessons in each development, and we are not taking advantage of improved reliability, common operations, and training.

Radically different approaches are needed to continue to meet the demand for increased software functionality, at a time when the Air Force has less money and staff to accomplish this task. ESC is expected to reduce significantly overall staffing levels in the next two years. To meet these challenges, a range of techniques and technologies are emerging and being endorsed by the Department of Defense (DoD). One of these is the product line approach.

The product line approach can offer specific advantages over a project-oriented development strategy. Development time and cost are significantly reduced. Organizations build core competencies, which are concentrated areas of knowledge that allow them to make more productive use of their staff. Products are engineered through recognition of changes within fundamental requirements or product line architectures, rather than built from scratch. In addition, under the product line approach, ESC can provide specific guidance to suppliers for vendor qualifications, development standards, and product definitions.

The product line approach to developing and maintaining DoD systems is supported by the Office of the Secretary of Defense. The Air Force is currently planning to implement product lines, consistent with direction and guidance from the DoD. A product line strategy is consistent with and complements the ongoing acquisition reform and streamlining initiatives within the Air Force [Perry 94][Lightning Bolt].

By exploiting commonalities and controlling the variabilities across related systems, the USAF can develop strategies that will enable the fielding of these systems faster, cheaper, and with added capability for the war fighter. For the product line concept to work, there is a fundamental change required in the way system requirements are defined. Users must be aware that the product line approach will produce a "less-than-100%" solution for their initially-stated requirements. The users must also be aware that they will be called upon to decide on the trade-offs associated with the elimination of some of these requirements.

Within this constraint, the product line approach will result in

- consolidation of core resources and competencies through identification of key business areas
- increased quality through the use of assets that are well understood and proven through retesting during multiuse
- building of tailorable features into assets to meet more than one user's needs
- minimizing of number of assets - reducing overall and repetitive development costs

- reduction of risk in software performance through known performance of assets
- improved time to production through reuse of technology, design, and assets
- increased interoperability through reuse of common architectures, interfaces, and protocols
- reduced training requirements for operations and O&M through similarities of components

3 Product Line Concept

This section presents separately the concepts for

- the role of architecture
- the management of product line assets including the product line architecture
- the development of systems in the product line

This section also includes scenarios for product line asset development and product line system production.

3.1 The Role of Architecture

The product line architecture provides the structure for building systems in the product line. The architecture is critical to the success of the product line approach. Key product line decisions are made during the process of developing or selecting the product line architecture. These include

- What are the critical issues in product line development (product line selection and inclusion, handling commonalities and differences, security, interoperability, reliability in product delivery)?
- How will the product line support interoperability/component integration issues (e.g., the Defense Information Infrastructure-Common Operating Environment (DII-COE) technical architecture)? Compliance and levels of compliance
  - legacy systems
  - new development
- What are the plans for change/evolution management within the product line?
- What are the key quality factors (for example, performance, security, dependability) that are essential for the product line?
- How will the product line take advantage of COTS/software sharing?
- How will systems be built (operational, system, and technical architectures)?

Before establishing the product line architecture, ESC must take an enterprise-wide look at the organization's products. A first step is segmenting these products into product lines through an identification and scoping process such as that described in the RMFF report [Haddad 96]. Mission area analysis to define the organization's business and the development of the organizational structure for product line development is a part of this step. The next steps in the decision process include product line specification, development of a product line architecture, and system architecture design for the individual product.

- **Specification of the product line.** Specification requires understanding the potential commonalities across current and future systems in the product line as well as variations that lead to different systems. This key step requires analysis of product line capabilities, those that are mandatory for each

system in the product line, and those that may be optional. In addition, the definition must provide for alternative capabilities, i.e., a choice among different capabilities, where appropriate.

- **Development of a product line architecture.** The product line architecture defines the components (mandatory, optional, alternative), component interrelationships, constraints, and guidelines for use and evolution in building systems in the product line. The product line architecture must support common capabilities identified in the specification and the potential variabilities within the product line. The product line architecture provides various views into the product line, including data, security, performance, and communication. This step will identify existing architectures and architecture fragments (component designs) that can be reused in new and updated product line architectures. Product line architecture guidelines will include factors for the use and evolution of the architecture.

- **System architecture design.** The SPO will select representatives from the product line organizations to form a product line architecture selection team. This team collaborates in product line production to determine architecture suitability for a new system. The team must assess the ability of the product line architecture to meet the specific system needs as defined by the user and SPO. This architecture assessment considers existing products in the product line as well as architectural constraints.

  Existing products may serve as a model for the new system, or the product line assets may support a prototyping capability. The architecture team must determine if the new system's needs can be met within the current product line architecture. If not, they must decide

  a. if the system needs can be relaxed, so that the product line architecture can be used

  b. if it is feasible to use parts of the product line architecture or to extend it for this new need and for future systems in the product line

  They may decide that system development cannot be performed with the product line approach and then employ alternate acquisition methods.

The architecture group works together with the SPOs and the engineering centers to develop product line architectures based on user needs. Figure 3 shows the architecture tasks that are part of product line architecture specification and those used in developing specific system architectures.

Within both the product line and system architecture design activities, it is necessary to address three key architectural considerations: product line requirements, physical hardware/software configuration and constraints, and architectural standards. These considerations lead to the operational, system, and technical architectures. [Horizon 95][Haddad 96]

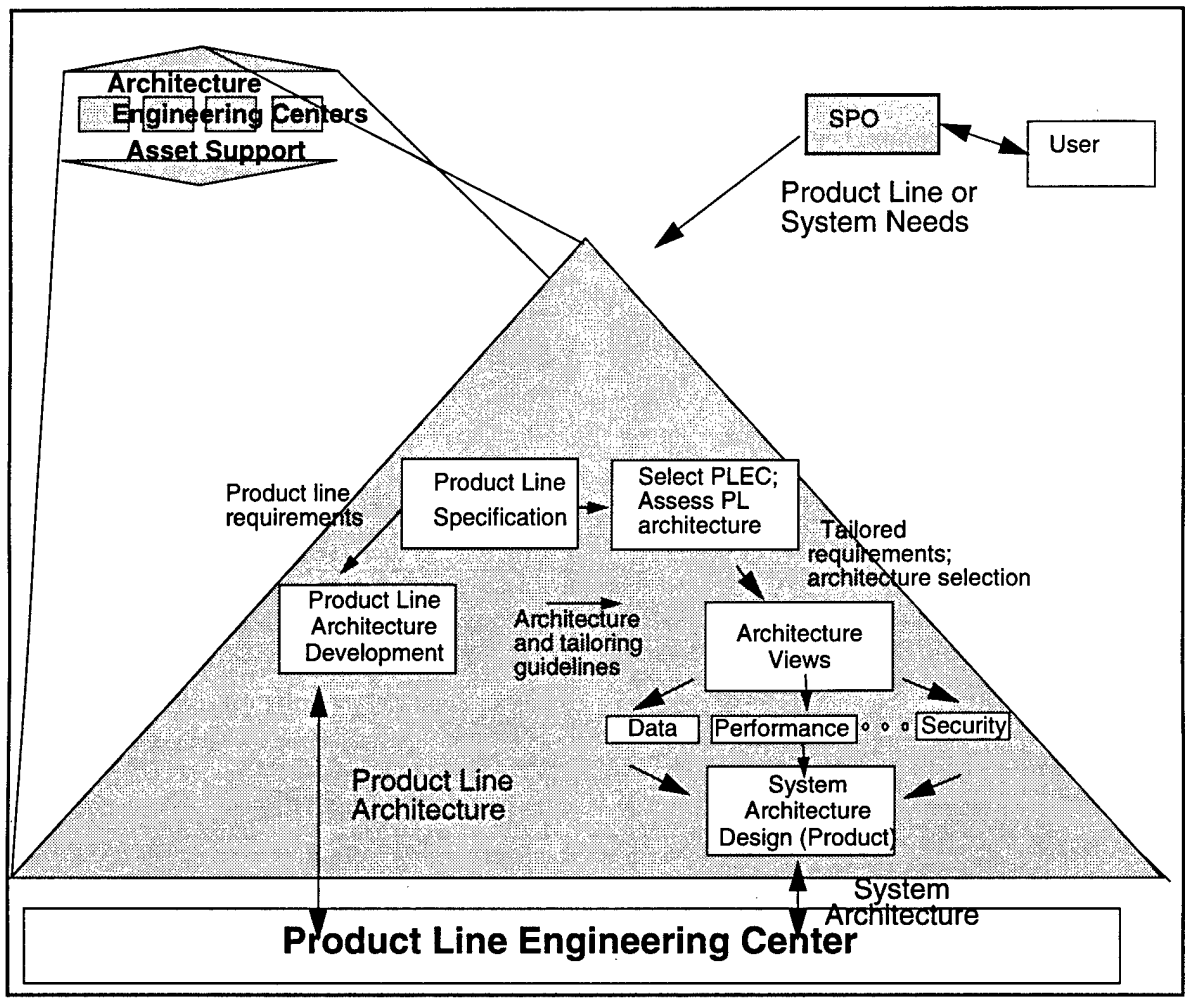

Figure 3: Architecture Tasks

- Operational architecture - reflects users' activities; describes system organization and interfaces, functional activities, data models, reusable components, and performance aspects such as volume, timeliness and sensitivity.
- System (physical) architecture - the fielded automated system; physical nodes and linkages represented by facilities, sensors, communications, and computer systems.
- Technical architecture - technical framework and set of rules from which automated systems can be developed; standards and common interfaces.The DII COE technical architecture is an example.

Architectural tradeoffs among these concerns stem from differing mission needs, threats, or specific operational requirements. They are essential to the product line and system architecture design activities and are also important considerations for interoperability and standardization. Figure 4 shows these activities contributing to the architecture design activity where

standards such as DII COE will influence system physical designs and drive application architectures. End-user systems will demonstrate the viability of the standards and indicate areas for improvement.

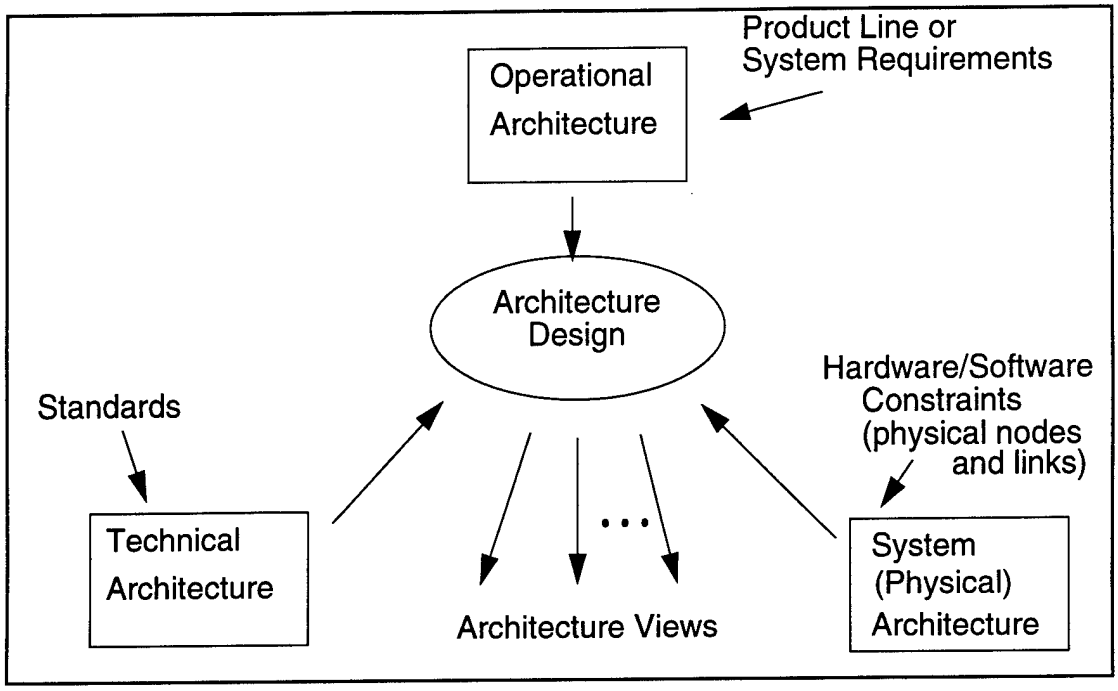

Figure 4: Architectural Context

3.2 Product Line Assets

Product line assets are the reusable resources that support the development of products in a product line. These assets are more than just software components. They include

- domain models
- product line architectures
- communication protocol descriptions
- user interface descriptions
- code components
- work breakdown structures
- application generators
- process components (methods, tools)
- designs, design standards, design decisions
- domain knowledge
- test plans and procedures
- requirement descriptions
- CM plans and tools
- performance models, metrics
- budgets and schedules
- prototypes
- COTS product profiles
- test scaffolding

Each development cycle of a system in the product line offers an opportunity to refine these assets.

3.2.1 Asset Support Activities

The activities required to identify and maintain product line assets include

- identifying, qualifying, and packaging reusable resources (enterprise-wide assets) for use in future development
- making them available within and across product lines at ESC (through a repository and other communication channels)
- maintaining configuration control on versions

And, in the case where a product line has made the commitment to leverage commercial investment by focusing on the integration of COTS products as a development method, it will be necessary to have the infrastructure in place to

- perform suitability testing of COTS products using a centrally-maintained facility

The Product Line Asset Support Group is primarily responsible for performing these tasks under this Concept of Operations. However, the asset group is supported by the other product line organizations. For example, in identifying enterprise-wide assets, the architecture group will play a major role as part of its task in developing product line architectures. This is especially the case for ESC-specific assets. For COTS products, the asset group will remain the major source for identifying and determining suitability of assets; however, the original contractor/developer retains responsibility for its own assets. Figure 5 shows the relationship of these activities to the other product line organizations.

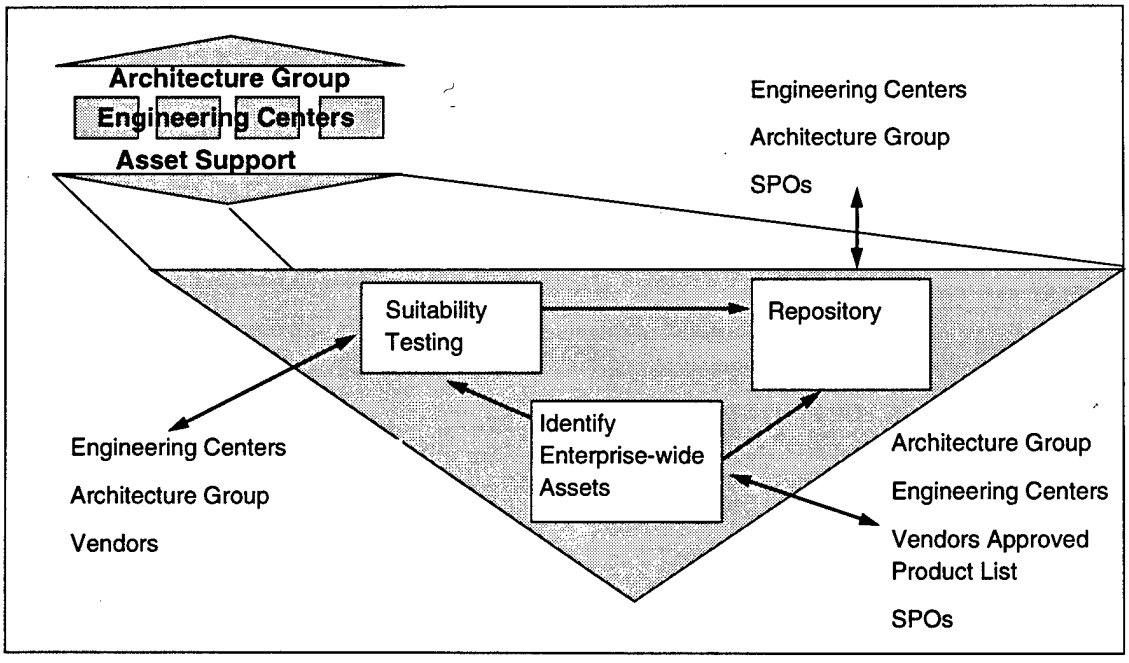

Figure 5: Product Line Asset Support Group Interactions

Identify Enterprise-Wide Assets

An important core product line effort involves the identification of reusable assets for use within and across product lines and the development of a reusable asset base. Legacy systems must be analyzed to identify and repackage existing software for possible use as reusable information and assets. Assets from legacy systems and new development include software, architectures, designs, criteria, and other information. This information will be maintained in a product line asset repository. Identification and packaging of these enterprise-wide assets will increase the asset base available to each product line organization.

Another ongoing task to support the identification and distribution of enterprise-wide assets is cross-product line analyses of these assets to identify opportunities for reuse of products and knowledge in other product lines. Technology transfer of this information, as well as emerging reuse techniques and methods across product lines, will be performed to maximize the benefits of the opportunities identified.

Repository

A repository of product line information acquired through suitability testing and identification of enterprise-wide assets activities will be maintained. This will include all of the kinds of assets stated above, organized according to the product lines. ESC-sensitive information will be available through an access-controlled repository. A list of the products tested and the results of suitability testing will be made available through a separately-maintained Product List. Eventually, an acquisition mechanism for COTS products may be provided in addition to the Product List.

The asset repository will accelerate and support availability of proven, reliable assets for incorporation into product line systems. As the repository is fully populated and the working relationships among the organizations mature, the opportunities for reuse will increase and the benefits of the product line approach will be realized.

Suitability Testing

Suitability testing is the process of determining if a COTS or Government off-the-shelf (GOTS) software product meets the architectural and functional requirements of a component area within a software architecture. The products are tested using a standard process to provide an objective analysis of the functionality and architectural capabilities using criteria that are derived from the architecture. COTS and GOTS products will be tested for suitability against product line architectures. Suitability criteria will be developed and maintained. The suitability criteria are derived from requirements and interfaces for component areas in product line architectures, and are used to perform suitability testing of software products. Results of suitability testing will be placed in the Approved Product List.

More complete information on product line asset support activities is available in the *Product Line Asset Support Concept of Operations* [Solderitsch 96].

3.3 The Development of Systems in a Product Line

The process for developing systems under a product line approach differs from the current process in two ways. These are

1. **Development from standard architectures** - A group of related systems shares a common structure defined as a product line architecture. In addition to structural properties, the product line architecture defines the components (mandatory, optional, alternative), component interrelationships, constraints, and guidelines for use and evolution in building systems in the product line. This architecture must support interoperability and component sharing with systems developed outside the product line. A new system is built by tailoring the product line architecture based on user requirements to produce a system architecture.
2. **Development using product line assets** - New systems are composed, adapted, or generated by populating the system architecture, to the greatest degree possible, with existing product line assets. This approach to development includes formal tracking of the product line assets and identification of opportunities for reuse of the assets in other product lines.

The new system architecture and any developed or modified assets become core assets for future development in the product line.

3.3.1 Working with the User

The System Program Office takes on a new role under a product line approach. The SPO continues to work with users to define operational requirements and deploy systems, but uses task order contracts available though the engineering center to develop and deploy these systems. The SPO also relies on the product line engineering center to provide domain expertise in key technology areas, such as radar, communications, and network control. Developing the expertise within the engineering center and the assets that embody that expertise will be funded through pooling funds across SPOs or direct core funding of the engineering center. Under this concept of operations, the engineering center is the designated developer of the system and also sustains the product line and its assets. Figure 6 illustrates responsibilities of the product line engineering center and the SPO.

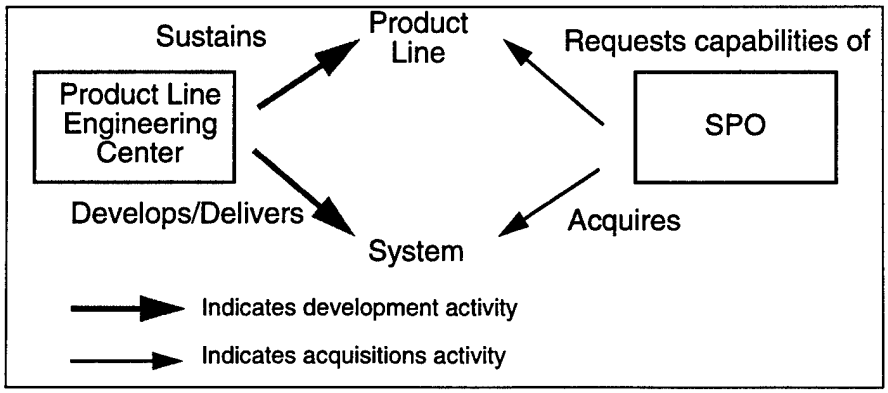

Figure 6: SPO and Product Line Center Responsibilities

The product line approach allows early demonstration of capabilities to the user through a baseline system supporting rapid prototyping and existing products in the product line. This early demonstration informs the user of

- how other products look (i.e., capabilities, structure, performance characteristics, etc.)
- the bounds of tailoring
- how requirements should be analyzed and how to manage expectations
- what are areas of risk, i.e., those not currently covered by the product line

Through demonstration, the user can then determine whether the product line approach will be sufficient to meet all or a subset of the user's needs.

3.3.2 Tailoring the Product Line Architecture

Systems acquired by the SPO involve different groups depending on the specific system requirements for that acquisition. The engineering center interacts with the Systems Architecture Group and the Product Line Asset Support group in system development. Figure 7 shows the relationship between the Product Line Engineering Center and the other organizations involved in product lines:

- The SPO provides the system requirements and a direct interface to the user community for the production of systems in the product line.
- The System Architectures Group (SAG) works with the engineering center in product line architecture definition and during product development, works with the SPO and engineering center in selecting and evolving the architecture.
- The Product Line Asset Support Group (PLAS) works with the engineering center to install the product line assets and during product development, identifies and qualifies new assets.

The product line engineering center, working with the other product line organizations, performs the three key tasks of product line production:

1. Support definition and maintenance of product line architecture.
2. Develop, evolve, and maintain product line assets.
3. Produce application systems (including systems that integrate across product lines).

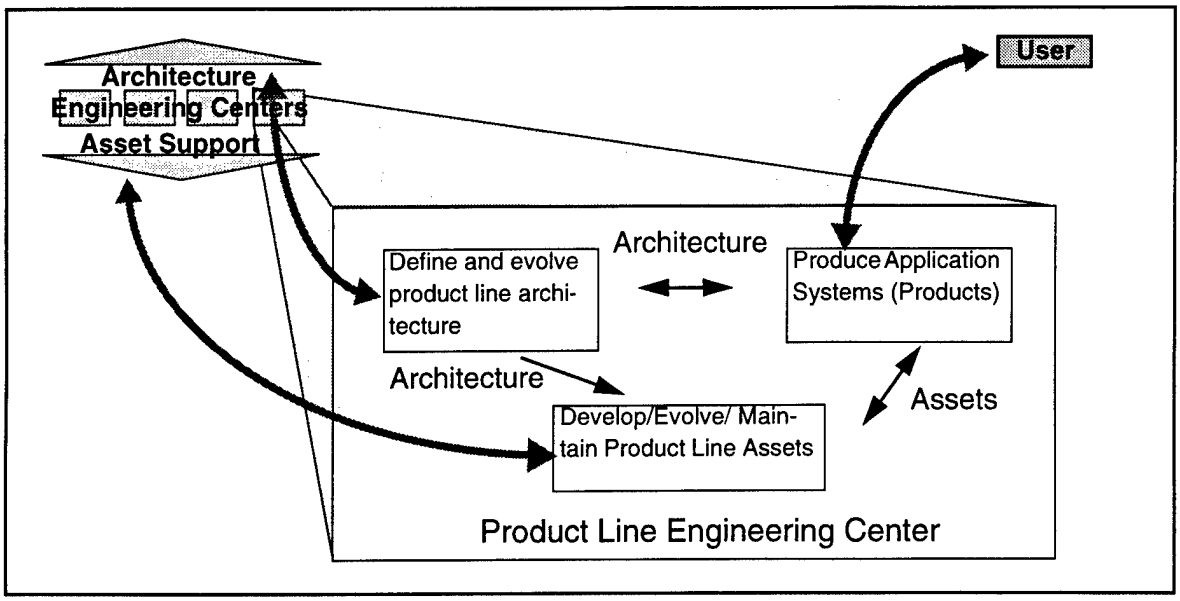

Figure 7: Engineering Center Interactions

The **product line architecture** is driven by system requirements, thus establishing the design structure for systems in the product line. The two-headed "Architecture" arrow indicates that the specific needs of a system in the product line will influence evolution of the architecture. The **assets** satisfy particular functional capabilities common to systems in the product line or support some aspect of product development (e.g., testing, documentation). They supply the key components used in building systems in the product line. The two-headed "Assets" arrow indicates that system needs will also influence the evolution of the product line assets. The third task is the **development and production of application systems**. Application systems are the successful integration of product line architectures and assets together with any unique, newly-developed, or identified commercial components that are necessary to fulfill a particular need of the system. These unique components become candidates for the asset base for future product line development.

3.3.3 Developing Systems with Product Line Assets

Figure 8 shows the process of delivering a software system or product. When a new product need is identified, the appropriate product line engineering center will work with a SPO and, through application engineering, produce a system meeting that need. Alternatively, the SPO may task the engineering center to provide assets to a contractor or directly to a user organization for development. The alternative means of product development offer tremendous flexibility to the SPO, yet retain the structure and consistency of the product line approach and avoid unnecessary duplication of effort and expenditure of scarce resources.

The figure illustrates that Product Lines A and B are established within the engineering center. Product Line A has two existing products, A1 and A2. The SPO and user have teamed with the engineering center and architecture group to understand the existing products within the product line, the range of capabilities offered by Product Line A, and the ability of the engineering center to tailor product line assets in order to determine suitability of the product line for their new needs.

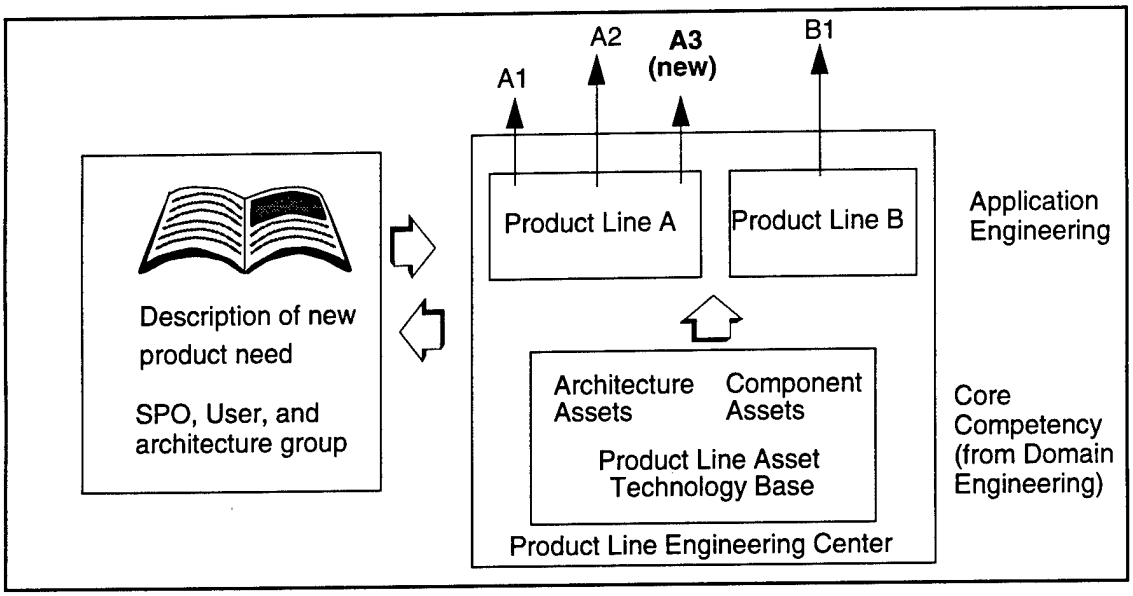

Figure 8: Product Line Systems Production Approach

The new product labeled A3 is developed mainly by integrating reusable assets plus new software written specifically for A3, in accordance with a product line architecture asset. The asset technology base represents the core competency, or product line knowledge of the engineering center. The asset group assists the product line center in identifying through domain engineering new assets not currently in the asset technology base,. These assets can support the development of A3. The asset group also helps determine whether custom software written for A3 should become assets for future system production in the product line.

Figure 9 shows the use of a common architecture to integrate alternative product line assets in creating products for product line A. Product A3 must meet the user requirements expressed in the description of new product need from Figure 8. Product A1 in the figure uses a mapping asset and two communication interfaces as well as other components not part of the current asset base. The new Product A3 uses a different mapping asset and one of the same communications assets. Both share the common command center architecture asset.

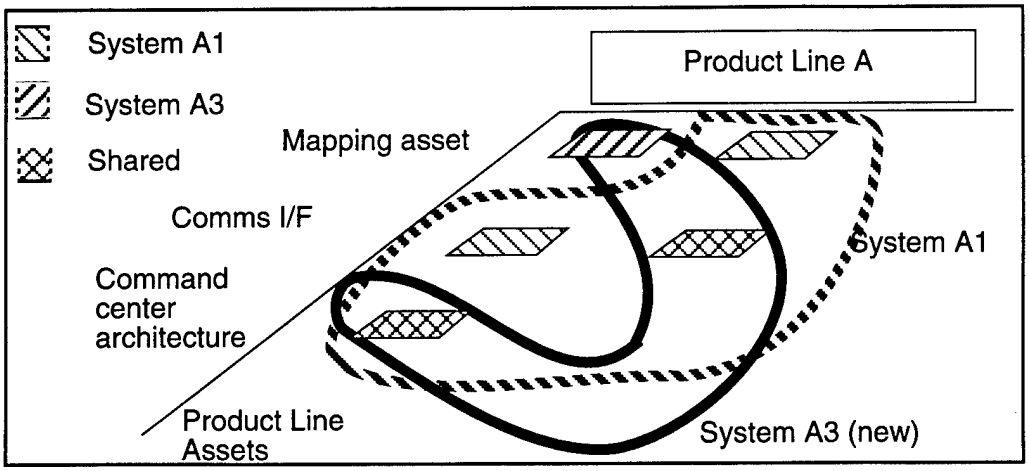

Figure 9: Building Systems from Product Line Assets

The following table summarizes the responsibilities of organizational elements.

Element	Primary roles and responsibilities
User	• defines and prioritizes user needs and clarifies requirements • analyzes prototypes • validates prototype results, where appropriate • determines which, if any, of the original requirements can be tailored to conform to product line standards • performs acceptance testing of delivered systems • uses delivered systems
Program Executive Office(PEO) and Designated Acquisition Commander (DAC)	• establishes policy for product line systems approach; policy for integrating across product lines and interoperability • ensures all programs are identified • approves identification of product lines • identifies and reserves funds for product line creation and development • approves each system to be developed under the product line approach
System Program Office(SPO) *Government*[a]	• manages system acquisition and development • serves as the primary interface to users and between other product line groups • performs product line identification • uses product line definition to assist in dialog with user for deriving operational requirements for systems • develops plans for integration across product lines • manages deployment and installation

Table 1: Responsibilities of Product Line Organizations

Element	Primary roles and responsibilities
System Architectures Group *Government /Industry*[b]	• establishes, monitors, and improves the ESC-wide processes used in the product line approach • identifies product lines with SPOs • with engineering centers, SPOs, and users, defines and maintains the architectures for ESC systems • with engineering centers, supports the evolution and reengineering of legacy systems for conformance to product line architecture • defines standards and methods for validating conformance with architectural definitions; responsible for "building permits" and certifying conformance
Product Line Engineering Center *Industry*[c]	• defines and maintains architectures for product lines within the engineering center and for integration across product lines • develops, procures, and evolves software (including COTS software) for product lines and for product line assets; configuration management • integrates and delivers systems by tailoring the product line architecture, specialization, and custom development per SPO requirements • supplies domain expertise in key product line technology areas • provides contract vehicle for use by SPO for product delivery
Product Line Asset Support Group *Industry*[c]	• qualifies products against product line architectures • identifies enterprise-wide assets (from COTS, GOTS, product line engineering centers) • provides a repository for ESC-wide engineering center use

Table 1: Responsibilities of Product Line Organizations

a. This organization is Government-staffed and managed.
b. This organization is joint Government/industry, managed by government.
c. These organizations are industry-staffed and managed, with Government oversight.

The PEO and DAC are entirely Government organizations and represent Government users. The other organizations shown in Table 1 are a mix of government and contractors.These organizations exist to support the product line approach to acquisition and development. Under this structure, each engineering center is supported by contractors that produce products in specific product lines.

3.3.4 Integrating Systems Across Product Lines

A product may require capabilities drawn from product lines in two or more product line engineering centers. The enterprise-wide processes used in the product line approach ease the integration of systems that cross product line boundaries. In Figure 10, Product Line Engineering Centers 2 and 3 include product lines indicated by the icons for each center. Architectures

and other assets from the product lines are both specialized (i.e., tailored to the specific system needs) and integrated to produce finished products for the user. For example, a user may need an integrated information distribution system. There may be individual product line centers for radio communication and message/text processing. In this case, a SPO will either select an integration contractor to provide the focus of the development or contract through an engineering center to produce the integrated system. While the SPO directs the specialization to meet customer needs, the process of specialization/integration will be the responsibility of the integrating contractor or of the product line engineering center selected by the SPO as integrator.

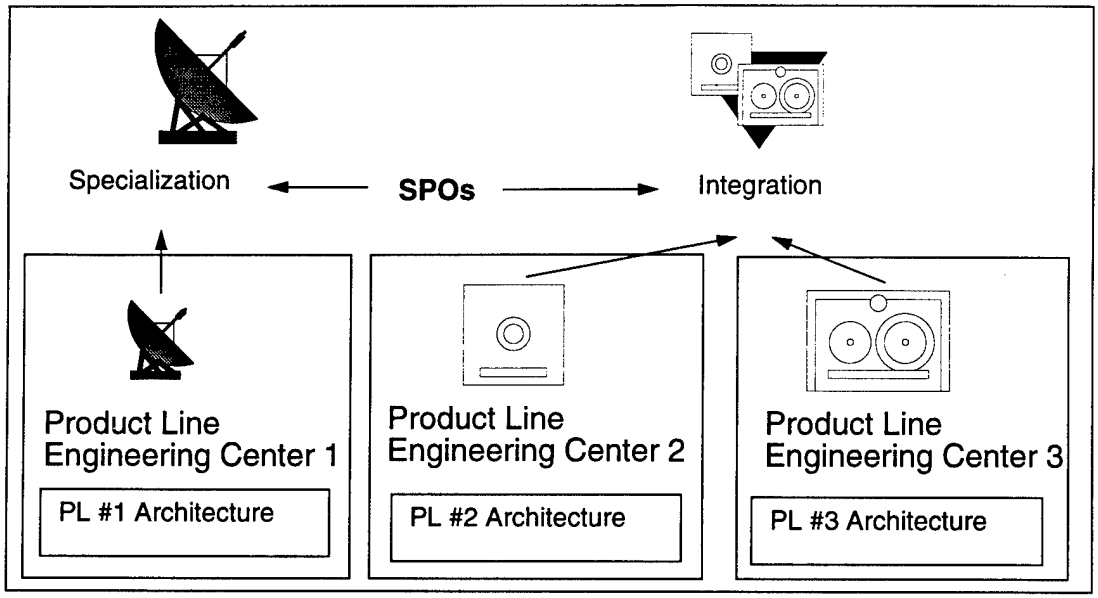

Figure 10: From Assets to Products

Table 2 describes the various development approaches to integration. The table lists four alternate approaches for developing products that integrate across multiple product lines or engineering centers. These four approaches offer ESC a range of selections for developing systems that integrate across product lines.

Integrator	Description
Contractor	The SPO works with a single integration contractor that utilizes and integrates products from individual product lines.
Engineering center	An individual engineering center is designated as lead center. The SPO uses an existing contract available within the lead center to secure an integrating contractor. The integrating contractor draws assets from the Asset Support Group and works with other centers to integrate a final product.

Table 2: Alternative Development Approaches for Integrated Systems

Integrator	Description
SPO	The SPO acts as the integrator, drawing resources from several centers.
Integration center	A new center is opened specifically to develop a product line (or product lines) of integrated C^4I products.

Table 2: Alternative Development Approaches for Integrated Systems

3.3.5 Maintaining Software Systems in the Product Line

The product line approach to maintenance requires continued use and improvement of the product line assets used during initial development. A SPO initiates a need for product improvement, whether corrective, perfective, or enhancing. Maintaining the system also entails maintaining the product line assets and modifying or extending them, if required, to meet the customer's needs for product improvement. Maintenance may also take advantage of assets that have been added to the asset base or improved by other system developments in the specific product line or in other product lines. Configuration management (CM) of assets will be a component of the infrastructure maintained by the asset support group. This CM system must take into account not only versions for systems, but also versions for assets used in each fielded system. As new versions of assets become available, current users must be able to obtain current configurations for these assets from this CM system and update their systems.

Several critical issues must be resolved to support this multitiered CM. Among these are the following:

- If an asset is upgraded, other assets that rely on it or interact with it will be affected. Maintenance of a system using the asset may opt for retaining the old version to avoid a ripple effect of changes.
- At what point in the evolution of a product line architecture does it become a new architecture? The evolution may require new assets, additional interfaces, etc. All products in the product line will likely not be upgraded.

Several options exist for managing the maintenance of systems in the product line:

1. The original engineering center may perform maintenance.
2. A maintenance center may be designated for some or all systems across several engineering centers.
3. Individual systems may be maintained by the user group or their designated maintenance organization.

Performing maintenance outside the original engineering center may place at risk the continual improvement of all systems in the product line. It is expected that the majority of the maintenance activities would be handled in the same manner as new system developments. The SPO will fund a new development effort that will call upon the resources of the product line

(product line architecture and components) for implementation. As a result, multiple versions of a component will exist in the product line architectures at any given time. This will result in a new dimension for configuration management to address.

3.4 Product Line Development Scenarios

Below are several scenarios describing the development of product line assets and the production of systems within a product line using assets.

3.4.1 Developing Product Line Assets

The Generic Command Center Architecture (GCCA) developed by the Portable, Reusable, Integrated Software Modules (PRISM) [Lonardo 93] program is an example of how product line assets can be developed. In this case, the GCCA is a fundamental asset, as it defines other assets that are necessary to develop applications in the Command Center Product Line. The GCCA was developed in two steps. The first was domain analysis: The analysis and development of a common process flow for functions that had to be provided in a command center. The second step was to map the features of the process diagram into a generic top-level design for command center systems; in other words, a product line architecture that would maximize software reuse. The emphasis was on using commercial off-the-shelf (COTS) software, because analysis indicated that it was cheaper. Therefore, the design was adjusted so that COTS software could provide functionality without modification. The unique applications' software components, not available off-the-shelf, were designed for as much reuse potential as possible.

In some cases it may be appropriate to adjust product line architectures to allow assets to be used in multiple product lines. The key is to create functional modularity within the product line architectures. DoD contractors have developed modular software for years, but the modularity was usually unique to a particular design and functions were not packaged in a manner that would facilitate reuse. The COTS software industry has provided the model of how to design packages with functional modularity so that the software components will have a widespread application. These same principles should be applied to our product line developments.

Software assets are identified and certified for use in a specific system software design. For the command center product line, these assets have been primarily COTS software, with the objective of certifying more than one COTS product for each of the functional modules / requirements. Thus, the product line architecture can be tailored to a user's needs by changing the components; then users are not dependent on a specific software vendor.

To remain viable, the product line assets must be updated to maintain compatibility with evolving information technology standards and functional software modules. New releases of COTS products must be evaluated for inclusion into the product line and the impact on the product line must be identified and demonstrated. The product line serves as a showcase of previously-delivered products and a repository for the latest versions of the product line assets.

3.4.2 Developing Products from a Product Line

Figure 11 illustrates a scenario for development within a product line engineering center. The Joint Tactical Information Distribution System (JTIDS) today provides a tactical information distribution system and will serve as a model for future systems in the communications product line. In the figure, the JTIDS SPO will team with the System Architectures Group and engineering center to identify the product line and assets to support a new requirement. The product line engineering center would then integrate capabilities (including ground/airborne communications and message processing) within the product engineering center to produce a new product.

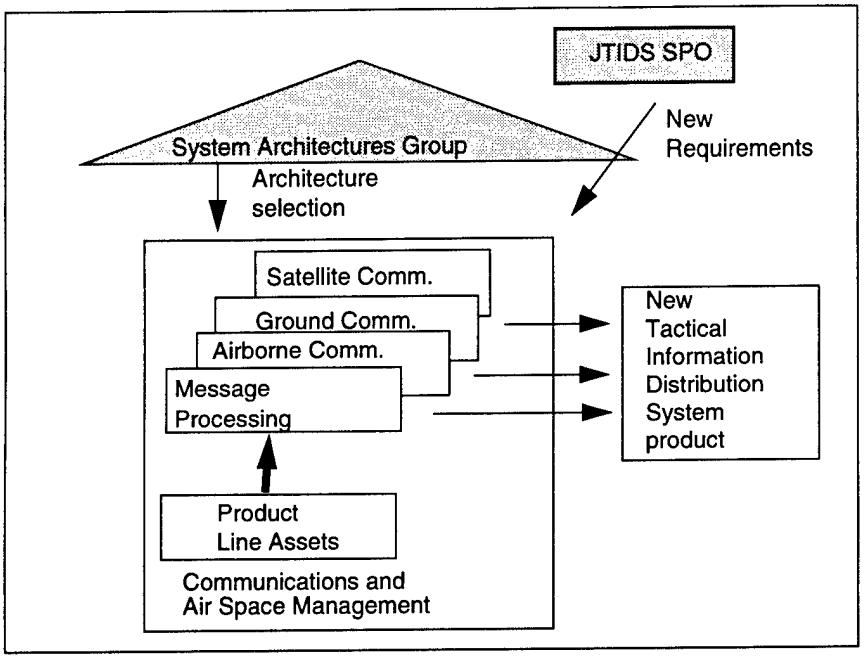

Figure 11: Development Within Product Line Engineering Center

3.4.3 Developing Integrated Products Across Product Lines

Development of many ESC products depends on integration across product lines and product line engineering centers. The following considerations are necessary in establishing the initial product line engineering centers within ESC:

- interconnections among product lines and product line engineering centers
- rationale for definitions of boundaries among product lines and centers
- operational context for product line definitions and architectures

The engineering centers and architectures group work with SPOs to carry out this role. Examples of "cross-product line" group products may include:

- TBMCS - mission planning and command centers
- Advanced Message Handling System - data fusion and command centers

As an example, a cross-product line configuration can exist to produce a new mission planning/battle management system. In Figure 12, the SPO, engineering centers, and architectures group work together to identify a lead product line engineering center for the development of the new product. The lead center works with other centers to specialize product line capabilities and integrate them into a new battle management product. The product integrates the following:

- mission planning capabilities that accept data from data fusion sources as input and support flexible execution and replanning
- command center capabilities that support situational displays

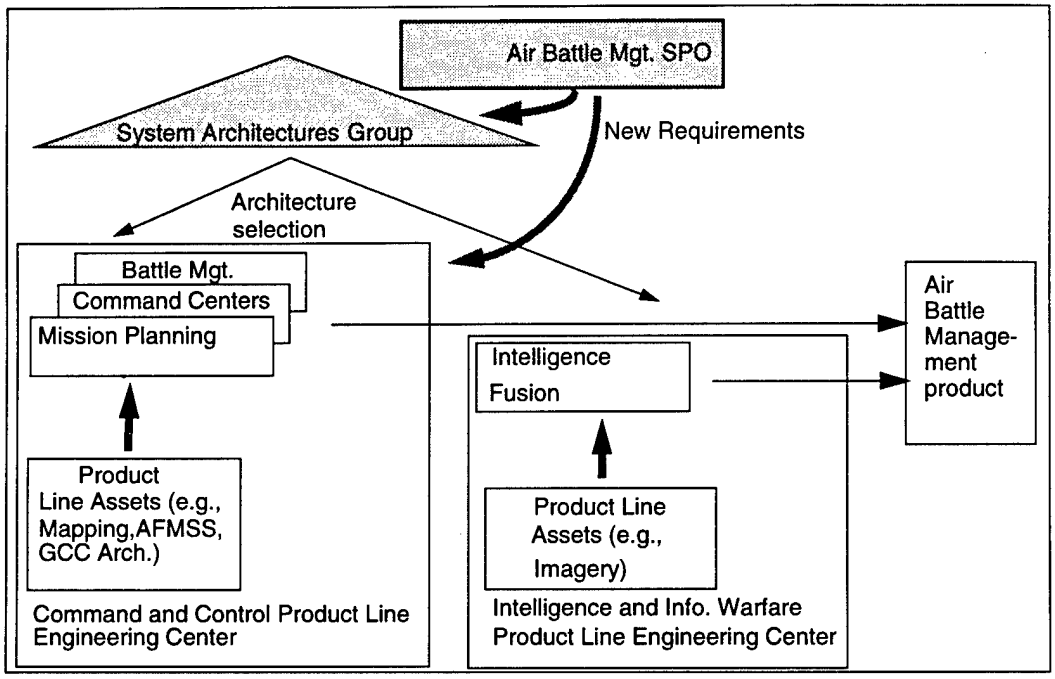

Figure 12: Integrated Air Battle Management System

4 Issues for the Transition Strategy

4.1 Concept of Operations for Transition

The product line approach is not a case of "one size fits all." There may be circumstances where the approach should not be followed due to cost, schedule, performance, capability, or insufficient commonality. All product lines may not be of the same maturity, so the procurement organization must consider risk factors in making a product line decision. Finally, a new set of requirements may fall outside the bounds of any existing product line. ESC must then determine if this should be a new area for continuing work and whether establishing a new product line is feasible. All of these factors would be considered as part of the business analysis.

To establish the product line approach, ESC should

1. use a pilot effort to serve as a test case for the product line engineering center concept
2. identify an existing product group to institute product line management strategies
3. identify an existing program or SPO to develop an evolution strategy for moving to a product line approach

After the initial approach is established, ESC should

1. Create the System Architectures Group, Product Line Engineering Centers and Product Line Asset Support Group to support product line production and qualification of assets. These organizations are not created for every new product line, only when existing centers cannot or should not support a new product line.
2. Analyze the current product mix to identify potential product lines. This is the effort reported in *Product Line Identification for ESC-Hansom* [Cohen 95]. The analysis reviews the current status of an organization's programs and the plans for future evolution. The organization must consider its current and anticipated customer base. It is possible that ongoing programs will need resources and/or relief in program milestones to assist in the development of the asset base and transition to product lines.
3. Define the assets for product line development according to desired product variety and customer needs. ESC must identify the processes that are part of asset creation including domain engineering, architecture description and assessment, and reengineering to deal with legacy systems. The System Architectures Group will be responsible for defining and monitoring these processes for the Product LIne Engineering Centers.

Along the transition path, ESC should look for new or ongoing programs that can immediately contribute to the product line approach. The Systems Architecture Group should seek ways to develop architectures and work with ongoing programs, e.g., Global Command and Control

Systems (GCCS), Regional/Sector Operations Command Center (R/SOCC), Theatre Battle Management (TBM), Space and Warning Systems Directorate, to make sure these systems produce common product line assets, or that the components they produce can become product line assets.

4.2 Impact of Transition

The transition to a product line strategy requires significant change in the existing organizations. The plan for transition must address the impact of change on organizational, management, and acquisition elements.

4.2.1 Organizational

ESC is currently experiencing a significant decline in resources and will need new organizational structures to utilize successfully the remaining resources. The product line approach will require special attention to bring together core competencies from across existing organizational structures. There appears to be significant redundancy of personnel and skills within the current two-letter organizations. Product line organizational restructuring will enable concentration and sharing of personnel and skills.

While the establishment of a product line philosophy will affect product users, PEOs, contractors, and support organizations, the principal effect will be on the direct users of the product lines: the SPOs. SPOs will coordinate the interaction of users, the architectures group, and the Product Line Engineering Centers for proposed systems. The SPO will rely on the engineering centers for technology expertise and development and on the engineering center, together with the architectures group and the Asset Support Group, to establish the specifics for system implementation and for configuration management as it affects the product line. The SPO will then choose a contractor, either from the set of PLEC contractors or elsewhere, to implement the system. During product sustainment, the SPO will review the existing product lines and architectures and establish a reasonable maintenance/upgrade/enhancement plan for the product.

4.2.2 Management

New incentives will be needed to support the management and use of a product line approach. Organization elements of key importance to ESC will be smaller than they are today, but no less critical. The following steps will help manage the technological changes that come with adopting a product line approach:

1. Promotion and reward potential must be addressed in the new structure.
2. General cultural changes will be needed at all levels. Management must drive these changes, even when they are the most affected.
3. Organizational elements will need to learn to get their job done, i.e., field a system, by relying on support and assets from other organizational elements. Not all aspects of a program will be under the control of one manager.

4. Product line orientation requires sharing of responsibilities and is impossible in a stovepiped organizational structure.
5. A managed process for product line development will support certification of system conformance to the product line architecture and successful use of product line assets.

4.2.3 Acquisition

Systems need to be acquired through methods that encourage the use of existing product line infrastructure and directly support the maintenance and upgrade of the infrastructure to support future needs. The current acquisition process funds software-intensive efforts on a program-by-program basis, with minimal funding allocated to product line infrastructure. Such investment is needed in support of a series of systems based on a common infrastructure. While significant changes are needed in the Program Objectives Memorandum (POM) process to get full benefits from product lines, ESC can address many near-term changes with local acquisition strategies. These local acquisition strategies include

- coordination of development activities among program offices by ESC
- elimination of redundant development
- use of funds to further the development of the product line for the benefit of all the contributing programs

ESC can also pool funds from all the programs that fall within a product line to pursue product line development using product line contractors. ESC may designate one program to establish the common infrastructure. Other program offices would contribute software assets to evolve the product line. Product line approaches also support procurement reform initiatives by taking advantage of commercial practices, existing COTS software products, and standardization of newly-developed product line components that can be reused across systems.

The PEO and DAC must ensure that every new program is examined for similarities with existing systems in mission and underlying functions. The goal is to focus new development on unprecedented areas and reuse product line assets as much as possible. Reuse of assets includes much more than software components. Design, architecture, requirements, and models are all assets for reuse. Acquisition strategies will need to ensure that every procurement leverages to the fullest the past investments and contributes to the assets to be used in future efforts.

Due to the increased focus on assets (including non-code assets, such as architectures) and their management for use across more than one system, product lines will bring ownership and liability issues to the forefront. The current acquisition regulations define a range of options for software and data rights, ownership, and liability issues that are most likely sufficient to address product line implementation. While the current acquisition guidelines provide a sound framework for dealing with issues of ownership and asset management, additional guidance on their application to product line concepts will be needed.

Ownership of assets within the product line approach is a key question. The Government organization should own the product line architectures or at least the right to use the architectures. The product line and the non-COTS software built to field a system may be government- or industry-owned. One model for the organizational structure of product line assets is

1. Government - Defines and owns Government Purpose License Rights (GPLR) to product line architectures to define component structure, connections, and constraints for a class of systems.
2. Industry - Develops components driven by market need and integrates components as part of a system within a product line. The government obtains GPLR while the contractor retains commercial rights.

4.3 Support Strategy

A basic element of the product line strategy is the continued maintenance and enhancement of the product lines and the corresponding architectures. The SAG, the PLAS, and the PLECs will cooperate in this effort, with the architecture group taking the lead. Architecture maintenance and enhancement is the primary responsibility of the SAG, which will lead architectural assessments to determine the needs for enhancement or, possibly, a new architecture. The PLEC is responsible for actual enhancements to the architecture and for fixing bugs in product line components and ensuring that new versions of COTS products are integrated into the product lines.The PLAS is responsible for maintaining the Product List supporting the product lines and for working with vendors to coordinate maintenance of their products. Updated products are provided to the various customers/users according to maintenance/upgrade agreements established at the initiation of a system acquisition. The maintenance and support of the product line architectures and components is a natural consequence of the product line development strategy.

5 Benefits and Challenges

By using the product line systems approach, organizations will deploy systems faster, at a lower cost, and with fewer Government and industry resources. Systems will be even more reliable because they will use common components that will have high reliability and proven performance characteristics. Training will be improved since common components will reduce the amount of training currently needed when transitioning between command and control systems. More commercial components will be available because industry will identify a larger market for their products when used across similar systems. Upgrades of components will also be promoted as industry recognizes a new market for their enhanced products.

The successful implementation of a product line systems approach presents challenges and barriers that are significant but surmountable. These include

- **Cultural** - Product line strategies mean organizations and managers have less direct control over their product developments and increased dependency on other organizations to understand their requirements and provide acceptable solutions. Giving up this control and the necessary dollars to support product line technology and application development may be difficult.
- **Strategic planning** - Product line planning is not only a management process that links related systems. The PEO or DAC, who have oversight for numbers of product lines, must consider the long-term needs of users and the ability of ESC to build for those users. They must take an enterprise-wide look at existing and planned products and look several years into the future in planning for product lines. The future year development plan (FYDEP) should focus attention on product lines as the means to satisfy the plan.
- **Need for tradeoffs** - The product line approach presents a tradeoff for the user between "build me the exact system I want" and "build me a system *almost* like what I want using the product line, saving on costs and time."
- **Resource ownership** - Who will "own" the product line components? How will they be funded? These issues require PEOs and DACs, as well as the Air Force Acquisition Secretariat, to accept transitioning from program-focused acquisition organizations and budgets to more commercial-like product organizations and budgets.
- **Recognition and reward** -The current acquisition system focuses recognition and rewards for personnel on delivered systems. Use of product line strategies necessitates a shift to also rewarding and advancing personnel for broadening the utility of products and facilitating their use within and across product lines.
- **User interface** - Users will experience close ties to the development organization within the engineering center. They should experience greater responsiveness through improved needs definition, refinement, and early demonstration. However, operational users must adjust to having more than

the program manager, PEO, or DAC as their dependency links to successful system upgrades or developments. This should not be difficult since users today are regularly dependent on a variety of sources for successful systems deliveries.

- **Effects of technological change -** The transition to a product line approach will mean significant changes in our current way of doing business. We must plan for the effects this will have on the individuals who must carry out the transition and also on those who will be operating under the new approach.

In spite of the magnitude of these issues, the transition can likely be achieved within existing budget planning.

6 Summary

The product line approach will not fit all system solutions, but should make a significant improvement in the timeliness, cost, and reliability of systems that are found to be suitable for its application. The business analysis must determine where and how to apply the product line concept of operations.

Use of product line strategies will enhance reliability of performance, schedule, and cost estimates. This dependability in delivery of systems will be achieved through elimination or narrowing of the "bounds of uncertainty" that accompany any estimating process. Where proven components are incorporated into the design and estimating process, we immediately improve our confidence levels surrounding performance, schedule, and cost expectations. Our assessments of risks and the uncertainties associated with resolving those risks are more narrowly bounded because of the improved ability to bound the expectations associated with use of product line components. Metrics are more readily available to assist in the estimating process and establishment of schedule and performance parameters.

Adoption of the product line approach requires thorough business analysis and careful planning. An organization must assess the business opportunities to ensure the appropriateness of adopting a product line approach. During transition, the organization must carefully monitor progress and make sure that product line groups are giving effective support to the SPOs.

Contractors work with several related programs to develop a common architecture and other assets. While it is not necessary for the Government to own all the assets in the product line asset base, it is necessary to have appropriate access to them. The acquisition and ownership policy for product line architectures is under investigation by several groups within the DoD. Implementation plans derived from this ConOps will include the results of these investigations to support decisions about responsibility and accountability.

Product line development evolves naturally from applying fundamental engineering concepts to meeting recurring needs. Recurring requirements provide the potential for economies of scale and reuse. Doing the job better, faster, and cheaper requires a focus on efforts that reduce the variable costs associated with system development and the total life cycle.

Appendix A References

[Cohen 95] Cohen, Sholom; Friedman, Seymour; Martin, Lorraine; Solderitsch, Nancy; & Webster, Robert. *Product Line Identification for ESC-Hansom* (CMU/SEI-95-SR-24). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 1995.

Summary: A joint product line identification team, with representatives from ESC, CARDS, MITRE, and the SEI, produced this report. Based on reviews of ESC programs, surveys of ESC two-letter organizations, and interviews with key program staff, this report identifies product lines for ESC and lays out a management structure for product line definition and application. This report does the following:

- establishes a framework for product line identification
- establishes boundaries and interconnections
- enumerates product lines and lists systems within them
- describes the current state and future evolution of the product lines

[Franklin 94] Franklin, Lt. Gen. C.E. *Acquisition Reform.* Presentation at the Information Systems Acquisition Conference. Arlington, VA, June 2-3, 1994.

Summary: ESC programs are generally variations of a theme, such as command and control centers, communications systems, intelligence centers, etc. . . . these product line systems can be identified in the future year development plan process and can be represented by a generic architecture, or domain, to facilitate software reuse and rapid prototyping.

[Haddad 96] Haddad, L.; Kogut, P.; Maymir-Ducharme, F.; & Saisi, R.O. *Software Reuse Initiative Reuse Methodology Fusion Framework Final Report* (CARDS CDRL: U001R1). Manassas, VA: Loral Defense Systems-East, 1996.

Summary: The RMFF is intended for use by Program Managers and Engineering Managers in selecting and integrating the appropriate reuse methods, taking into consideration the organization's existing methods, work-products and software engineering environment (tools).

[Horizon 95] Air Force Deputy Chief of Staff. Command, Control, Communications and Computers, Policy and Strategy Division. *Horizon 95.* Washington, D.C.: The Pentagon, 1995.

Summary: The Horizon concept was developed in 1993 in recognition of the importance of information technology for the Air Force. The first version focused on information architectures by advancing a vision of an integrated and responsive global infosphere supporting *Global Reach, Global Power* objectives. This updated edition expands upon the original by establishing 21st century Air Force information infrastructure objectives and by planning for rapid integrating of evolving technology with the current and future infrastructure.

[Lightning Bolt] Office of the Secretary of the Air Force/Acquisition (SAF/AQ) Lightning Bolt Initiatives [online]. Available WWW <URL:http://www.safaq.hq.af.mil/SAFAQ/acq_ref/bolts> (1995-96).

Summary: Air Force acquisition reforms.

[Lonardo 93] Lonardo, G. G. & Wallin, J. D. *Generic Command Center Architecture Report for the Portable, Reusable, Integrated Software Modules (PRISM) Program.* Hanscom AFB, MA: Electronic Systems Center, 1993.

Summary: The purpose of this document is to present the PRISM Generic Command Center (GCC) software architecture. The PRISM GCC architecture is intended to serve as an implementation framework for the future development of command center systems. The primary objective for PRISM is to validate the concept of developing command center systems through the integration of off-the-shelf, reusable software components. Developing an open system-compliant, standards-based architecture is the first step towards accomplishing that objective.

[Perry 94] Perry, William J., Secretary of Defense. *Acquisition Reform: A Mandate for Change.* Washington, DC: Department of Defense, 1994.

Summary: To support acquisition reform, this report recommends the adoption by DoD of business processes characteristic of world-class customers and suppliers (including processes that encourage DoD suppliers to do the same). The report also recommends relief from the requirement to impose Government-unique terms and conditions on its contractors to the maximum extent practicable.

[Solderitsch 96] Solderitsch, N. *Product Line Asset Support Concept of Operations* (STARS-VC-K017R1/001/00). Manassas, VA: Loral Defense Systems-East, 1996.

Summary: This document describes the Concept of Operations for the Product Line Asset Support group of the Electronic Systems Center, Hanscom AFB. It describes the activities to be performed in implementing the roles and responsibilities of the group and how they relate to the other ESC Product Line Organizations.

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS None
2a. SECURITY CLASSIFICATION AUTHORITY N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for Public Release Distribution Unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) CMU/SEI-96-TR-018	5. MONITORING ORGANIZATION REPORT NUMBER(S) ESC-TR-96-018
6a. NAME OF PERFORMING ORGANIZATION Software Engineering Institute 6b. OFFICE SYMBOL (if applicable) SEI	7a. NAME OF MONITORING ORGANIZATION SEI Joint Program Office
6c. ADDRESS (city, state, and zip code) Carnegie Mellon University Pittsburgh PA 15213	7b. ADDRESS (city, state, and zip code) HQ ESC/AXS 5 Eglin Street Hanscom AFB, MA 01731-2116
8a. NAME OFFUNDING/SPONSORING ORGANIZATION SEI Joint Program Office 8b. OFFICE SYMBOL (if applicable) ESC/AXS	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F19628-95-C-0003
8c. ADDRESS (city, state, and zip code)) Carnegie Mellon University Pittsburgh PA 15213	10. SOURCE OF FUNDING NOS. PROGRAM ELEMENT NO: 63756E PROJECT NO.: N/A TASK NO: N/A WORK UNIT NO.: N/A
11. TITLE (Include Security Classification) Concept of Operations for the ESC Product Line Approach	
12. PERSONAL AUTHOR(S) S. Cohen, S. Friedman, L. Martin , T. Royer , N. Solderitsch, R. Webster	
13a. TYPE OF REPORT Final 13b. TIME COVERED FROM TO	14. DATE OF REPORT (year, month, day) August 8, 1996 15. PAGE COUNT 34
16. SUPPLEMENTARY NOTATION	

17. COSATI CODES			18. SUBJECT TERMS (continue on reverse of necessary and identify by block number)
FIELD	GROUP	SUB. GR.	product lines, software reuse, acquisition reform, product line architecture, product line assets

19. ABSTRACT (continue on reverse if necessary and identify by block number)

This document describes the Concept of Operations (ConOps) and transition strategy for the product line approach to software systems development at the Air Force Electronic Systems Center (ESC), Hanscom Air Force Base, Massachusetts. This document defines the organizations implementing the product line approach and the processes used by the organizations. It describes the roles and responsibilities, and the relationships among the organizations. The processes needed to implement software system development using the product line approach are described at a high level and will be further detailed and refined as the product line approach is implemented at ESC.

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20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ■ SAME AS RPT ☐ DTIC USERS ■	21. ABSTRACT SECURITY CLASSIFICATION Unclassified, Unlimited Distribution
22a. NAME OF RESPONSIBLE INDIVIDUAL Thomas R. Miller, Lt Col, USAF	22b. TELEPHONE NUMBER (include area code) (412) 268-7631 22c. OFFICE SYMBOL ESC/AXS (SEI)